User's Guide

DCAM Frame Capture Development Kit

(using the UC1394a-3 MCM)

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1 Preface

This document describes software development for the UC1394a-3 MCM using the module support library from Orsys. The module support library is a collection of declarations and low level drivers that allow to access hardware on the board, such as loading the FPGA, using the UART as debug interface etc. This document also contains a detailed explanation of the IEEE1394 interface. Furthermore it describes the environment that the carrier board adds to the UC1394a-3 MCM along with some quick start examples.

1.1 Document Organization

This document is organized as follows:

- Chapter 2 gives a brief overview of the whole system and its interfaces
- Chapter 3 shows how to do the first steps with the kit
- Chapter 4 gives an introduction to software development
- Chapter 5 describes the application examples
- Chapter 6 documents the module support library
- Chapter 7 introduces the FPGA development option
- Chapter 8 explains the abbreviations that are used throughout this document
- Chapter 9 lists documents that contain further information

1.2 Documentation Overview

This chapter lists the documentation from Orsys that is shipped together with the DCAM frame capture development kit. Further documents from other vendors are listed in chapter 9 and are referenced throughout the document in square brackets.

UC1394a-3 Hardware Reference Guide [14] (`UC1394a-3_hrg.pdf`):
Describes the hardware of the UC1394a-3 MCM. It is intended to get an overview of the multi chip module and the features provided by it.

DSP Master BSP User's Guide [15] (`DSP_Master_BSP_UG.pdf`):
Describes the DSP Master Board Support Package (BSP). This BSP adds an asynchronous 16-bit peripheral interface and a software streaming interface to the UC1394a-3 MCM. The user's guide includes FPGA register description and FPGA register programming documentation for these interfaces.

DCAM API User's Guide [17] (`DCAM_UG.pdf`):
Describes the DCAM application programmer interface (API) for controlling digital cameras.

Ultra-compact Small Carrier Hardware Reference Guide [18] (`uc_sc_hrg.pdf`):
Describes the carrier board that is used in the DSP Development kit, including schematics and hints for power supply configuration.

1.3 Notational conventions

Names of registers, bit fields and single bits are written in capital letters.
Example: LLC_VERSION

Names of signals are also given in capital letters, active low signals are marked with a '/' at the beginning of the name.
Example: /RESETIN

Configuration parameters, function names, path names and file names are written in *italic* typeface.
Example: *dev_id*

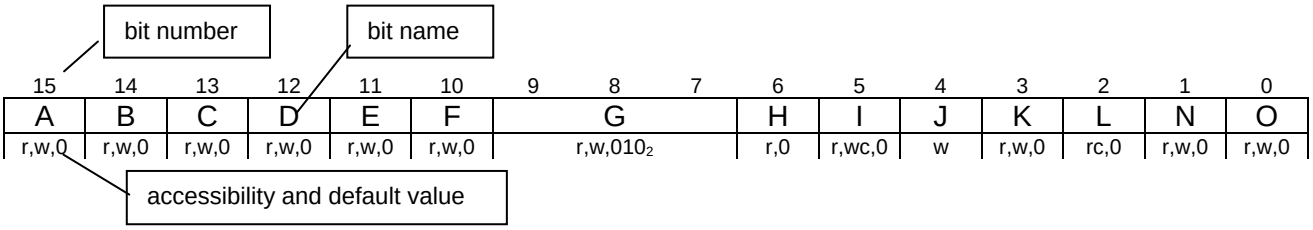
Source code examples are given in a small, fixed-width typeface.
Example: `int a = 10;`

Menus and commands from menus and submenus are enclosed in double-quotes. Example:
Create a new project using the "Create Project..." command from the "File" menu.

The members of a bit field or a group of signals are numbered starting at zero, which is the least significant bit.
Example: CFG[4:0] identifies a group of five signals, where CFG0 is the least significant bit and CFG4 is the most significant bit.

If necessary, numbers are represented with a suffix that specifies their base.
Example: $12AB_{16}$ is a hexadecimal number (base 16 = hexadecimal) and is equal to 4779_{10}.

The bit fields of a register are displayed with the most significant bit to the left. Below each bit field is a description of its read / write accessibility and its default value:


bit number
bit name
15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
A B C D E F G H I J K L N O
r,w,0 r,w,0 r,w,0 r,w,0 r,w,0 r,w,0 r,w,010₂ r,0 r,wc,0 w r,w,0 rc,0 r,w,0 r,w,0
accessibility and default value

legend:

r	bit is readable
rc	this bit is cleared after a read
r,w	bit is readable and writeable, reading yields the previously written value unless otherwise specified.
w	bit is writeable, read value is undefined
wc	writing a '1' to this bit clears it
w,0	bit is write-only, reading always yields 0.
0	default value

1.4 Trademarks

TI, Code Composer, DSP/BIOS and TMS320C5000 are registered trademarks of Texas Instruments.

Microsoft® and Windows® are either registered trademarks or trademarks of Microsoft Corporation in the United States and/or other countries.

Hypterterminal is a trademark of Hilgraeve Inc.

All other brand or product names are trademarks or registered trademarks of their respective companies or organizations.

1.5 Revision history

Revision	Changes
1.2	First release

2 Kit Overview

The DCAM frame capture development kit consists of a UC1394a-3 MCM mounted on a UC1394a Small Carrier board.

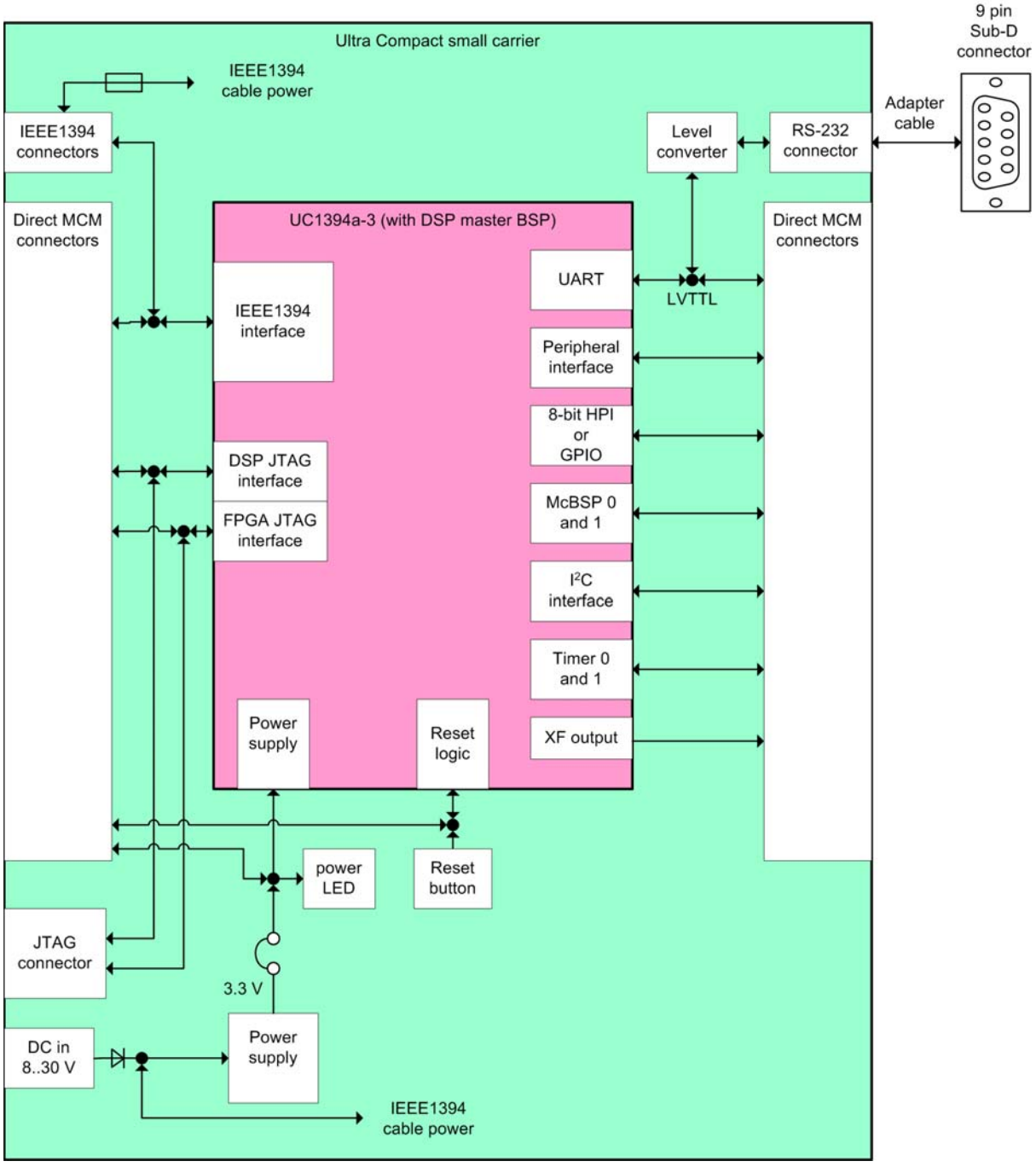


Figure 1: DCAM frame capture development kit block diagram

2.1 UC1394a-3 MCM

The UC1394a-3 MCM implements most of the functionality of the DCAM frame capture development kit. It is a high performance DSP / FPGA system that provides all of the interfaces shown in Figure 1 and a complete hardware environment for user applications. After development is finished, the UC1394a-3 can be easily integrated into a customized hardware environment. Its small size and low cost makes it an ideal solution for end-product usage. Further, the

implementation as a multi chip module (MCM) allows similar handling as of integrated circuits, therefore mass production is supported.

The following interfaces and signals are provided without any FPGA design required:

- 2 McBSPs
- 8-bit HPI or general-purpose IO
- UART with LVTTL level
- I^2C interface
- general-purpose output (XF)
- 2 DSP timer inputs/outputs
- IEEE1394 interface
- DSP JTAG interface
- FPGA JTAG interface
- system reset input
- system reset output
- external interrupt input to the DSP

These interfaces are described in the Hardware Reference Guide [14] of the UC1394a-3.

The UC1394a-3 is equipped with the DSP master board support package (BSP). This BSP adds an asynchronous parallel bus peripheral interface and a software streaming interface to the MCM. The DSP master BSP is described in [15].

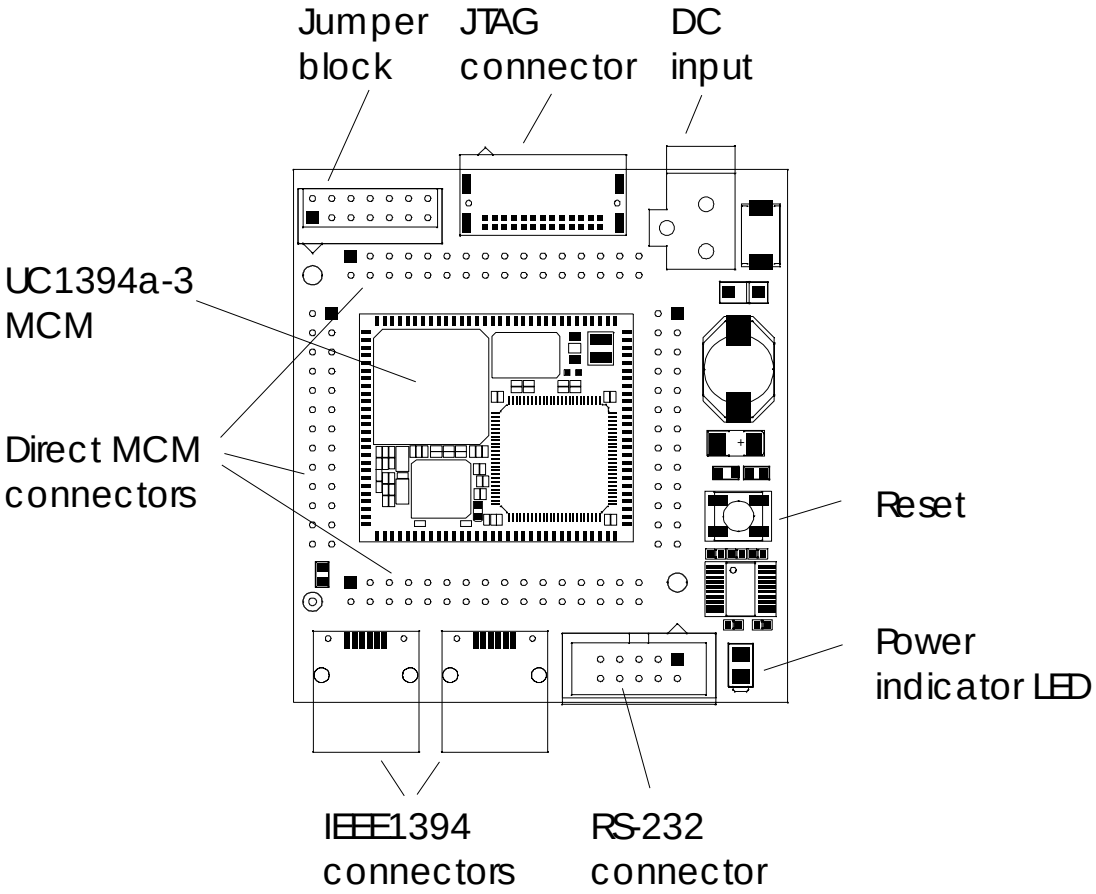
2.2 UC1394a Small Carrier

The Ultra Compact small carrier provides all necessary connectors and control elements:

- Two 400 Mbps IEEE1394 ports with standard 6 pin connectors.
- Connectors that provide direct access to each MCM signal
- Power supply either from an external source or over the IEEE1394 cable
- A red LED as power indicator
- A reset button
- A JTAG connector for service purposes and software/FPGA development option[1]
- RS-232 level converter and RS-232 connector that provides the UART interface with RS-232 voltage levels
- A Jumper block (not used by DSP Master BSP, can be used by customized BSP's)

The carrier board is intended as a development aid, which is used in the prototyping stage of a project. In the end product, the UC1394a-3 MCM will typically be used standalone. However, the complete kit (MCM mounted on carrier) is also available in quantities. A detailed description of the carrier hardware, including schematics and component lists can be found in [18].

[1] Software and FPGA development is available in other Orsys products.



2: Small carrier board connector locations

2.3 Interfaces and Connectors

2.3.1 Software Streaming

The streaming interface is implemented by the DSP Master BSP and is described in detail in [15]. Software streaming allows to transfer large amount of data between the DSP and IEEE1394 with minimal overhead. Data transfers are buffered by a FIFO, so that the DSP can operate independent of the IEEE1394 timing. Streaming transfers are unidirectional and must be set up for a particular direction before operation is started. The maximum transfer rate for streaming is 32,768,000 byte/s. Software streaming uses isochronous streaming as defined by the IEEE1394 standard. Isochronous streaming is explained in chapter 2.3.3. Software streaming programming is described in [15] and in [17].

2.3.2 Peripheral Interface

This interface allows to connect to a wide range of user-defined peripherals. The peripheral interface is implemented as a parallel bus interface with asynchronous control signals. All signals of the peripheral interface of the MCM are directly routed to the UC1394a Small Carrier connectors.

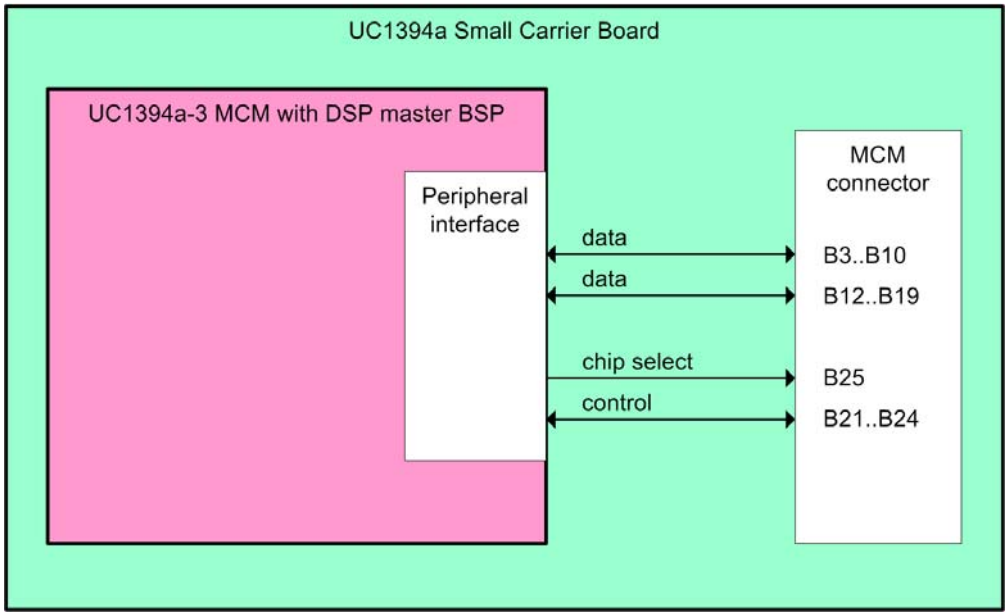


Figure 3: Block diagram of the peripheral interface

A detailed functional description of the peripheral interface and its signals are described in [15].

2.3.3 IEEE1394 Interface

The UC1394a-3 MCM has two 400 Mbps IEEE1394 ports. These ports are routed to two standard 6-pin IEEE1394 connectors on the carrier board. Using these two ports, the DCAM frame capture development kit can be inserted anywhere in an existing IEEE1394 network. Since the IEEE1394 physical layer acts as a repeater, no processing power is required for transferring data from one port to the other.
For transferring data between the DCAM frame capture development kit and the IEEE1394 network, three transfer methods are available which are described in the following chapter.

2.3.4 IEEE1394 Data Transfer Methods

IEEE1394 provides three different methods for transferring data:

- isochronous streaming
- asynchronous streaming
- asynchronous transactions

Asynchronous transactions are handled by the IEEE1394 API, whereas isochronous and asynchronous streaming is only set up by the API and then performed by FPGA register accesses.

2.3.4.1 Isochronous Streaming

In isochronous streaming, data is transferred in regular intervals, called cycles. In each cycle, one data packet can be transferred. The size of these data packets determines the maximum data bandwidth which can be calculated as *max_bandwidth* = *packet_size* * 8000 *packets_per_second*.
The cycle clock is 8kHz, therefore, packets get sent every 125 µs. Before transmission is started, the transmitter reserves the necessary amount of bus bandwidth at a central location on the bus, the isochronous resource manager. This and the fact that isochronous packets have precedence

over asynchronous packets guarantees, that the bus provides enough capacity for the transfer. Isochronous streaming is an excellent solution for transferring image data from a camera. Isochronous transfers are multicast transfers which are identified by a channel, so there is always one talker but there may be one or more listeners. The transfer is typically done without any software overhead and is therefore quite fast. Error detection is done at the receiver side.
Isochronous streaming is well suited for

- large amounts of data
- data distribution to several devices
- data that occurs in regular intervals

Figure 4 shows a part of an isochronous stream, recorded with an analyzer. The large blocks are isochronous packets with maximum size (4096 bytes). The isochronous packets are preceded by a cycle start packet, which indicates the start of a new cycle. On the UC1394a-3 MCM, packets are only transmitted, when enough data is present in the FIFO. Otherwise, the corresponding cycle will be empty, thus, no packet is transmitted. Figure 5 shows an example for this.

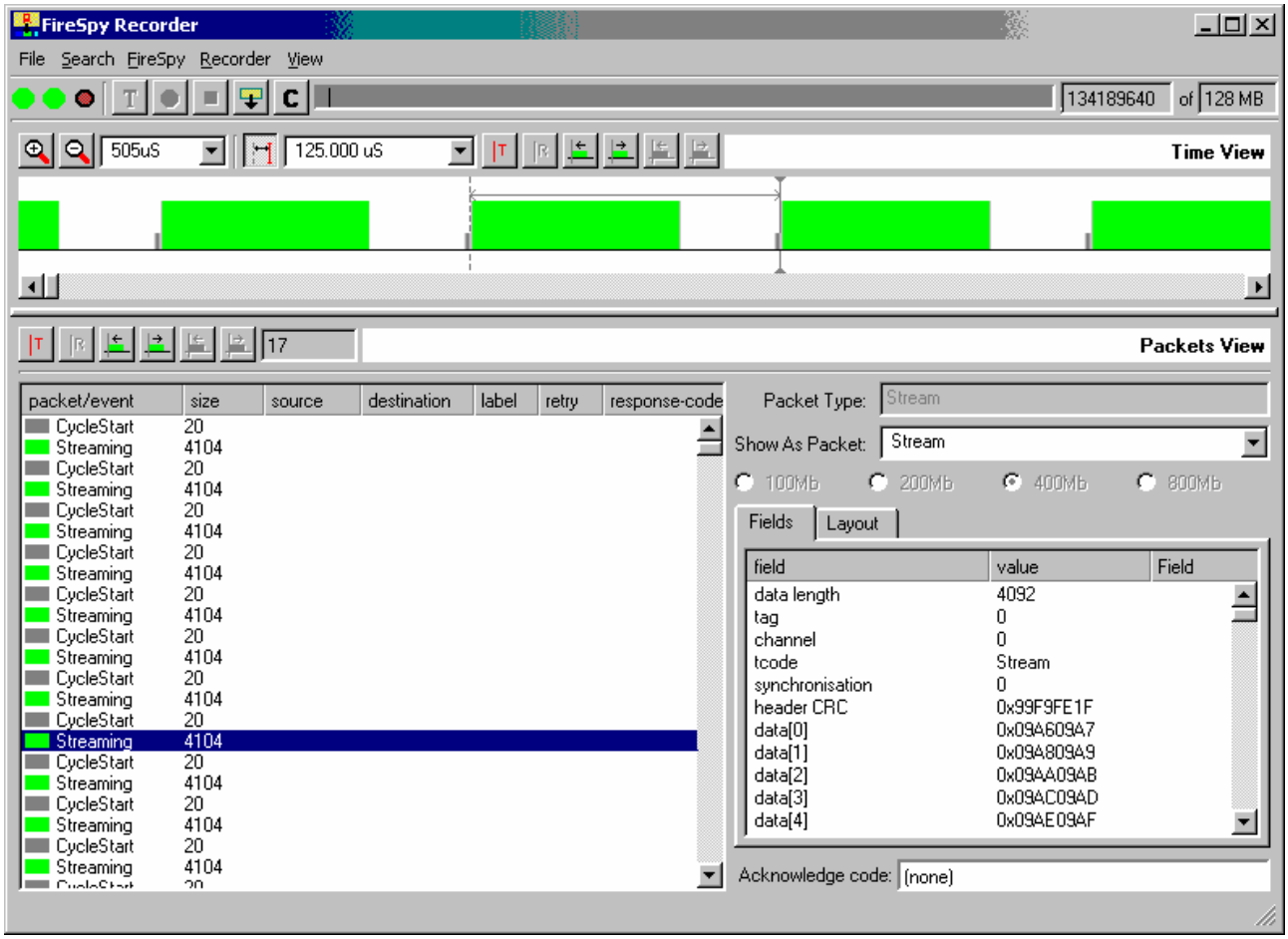


Figure 4: Isochronous data, recorded from the IEEE1394 bus with an analyzer

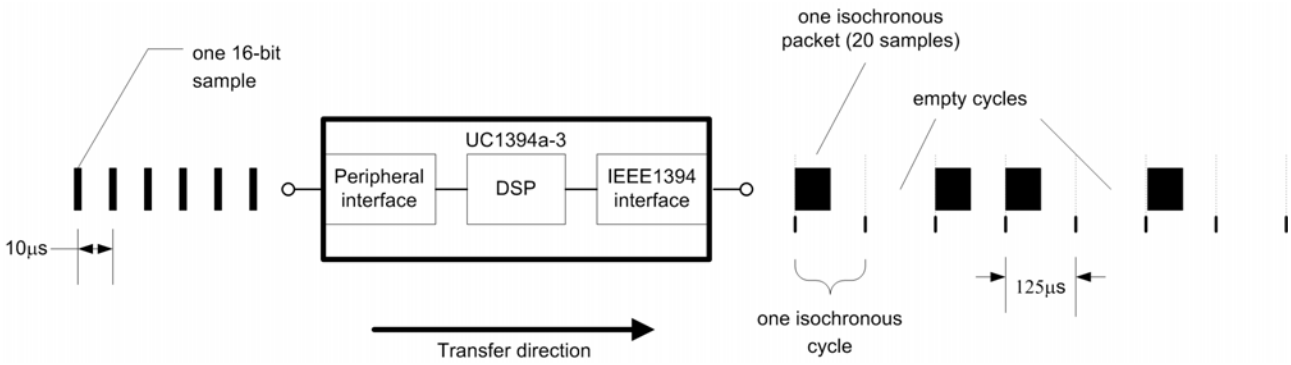


Figure 5: Isochronous packet assembly, sampling at 100kHz, 16bit, packet size = 40 bytes

2.3.4.2 Asynchronous Streaming

Asynchronous streaming is similar to isochronous streaming. Asynchronous streaming uses the same data packets as an isochronous transfer. Packets may be sent anytime, provided that the bus is free. Bus bandwidth is not guaranteed here, so the transmission of a packet may be blocked by other transfers on the bus. At the receiver side it makes no difference whether isochronous or asynchronous streaming is used. Asynchronous streaming should be used, when latency requirements don't allow isochronous streaming and bus bandwidth can be guaranteed by system design.

2.3.4.3 Asynchronous Transactions

Asynchronous transactions are handled by the IEEE1394 API. Each data packet that is sent, receives a response from the addressed device. Asynchronous transfers can occur at any time (provided that the bus is free). They are point to point transfers, so the originator of the transfer must know who to talk to. An asynchronous transfer consists of a request that is sent to the destination device, and a response that the destination device sends back. This enables error checking at the sender. Asynchronous transfers are well suited for

- data that occurs randomly (e.g. control and status information)
- transfers where the originator of the transfer must be informed about the status of each single transfer

2.3.4.4 Plug & Play features of IEEE1394

When devices are connected to or disconnected from the IEEE1394 network, node ID's are automatically assigned for the connected devices. This is done by the chipset without any software intervention. Independent of the node ID, most devices provide some more information about themselves. There is an area within the IEEE1394 address space that is called configuration ROM. The configuration ROM holds information about

- the manufacturer of the device
- device serial number
- software interface of the device

The serial number together with the manufacturer form a world wide unique 64 bit ID. Using this 64 bit ID, the device can be identified independently of the network topology or the currently assigned node ID.

The next higher level of identification is the protocol level. By default, the UC1394a-3 when equipped with the DSP Master BSP identifies itself as a device running a generic protocol specified by Orsys. This protocol can be used on a host PC to load appropriate device drivers. Customized protocol identification is available at Orsys on request.

2.3.4.5 Power Distribution over IEEE1394 and Isolation

The IEEE1394 standard defines a 6-wire cable, that allows to supply devices over the cable. This is often used for digital cameras. To operate the UC1394a-3 powered from the IEEE1394 cable, an external voltage regulator is required. The IEEE1394 standard allows up to 10W power consumption for a device. The IEEE1394 interface of the UC1394a-3 is directly connected to the remaining circuit. There is no galvanic isolation between the IEEE1394 cable and the local power supply. In a custom hardware design, the VG pin of the 1394 connector must be connected to the GND pins of the UC1394a-3. For a detailed description of power distribution and isolation please refer to [14].

2.3.5 UART Interface

The UC1394a-3 MCM has an UART interface that can be used for standard asynchronous communication. Different baud rates are supported as well as RTS/CTS handshake. The UC1394a Small Carrier board uses a level converter to convert these signals to RS-232 level. How to program the UART interface is described chapter 6. The distribution media contains an application example for the UART in the *hello* folder. The UART interface uses 2 data lines and 2 handshake lines. A detailed description of the UART signals can be found in [14].

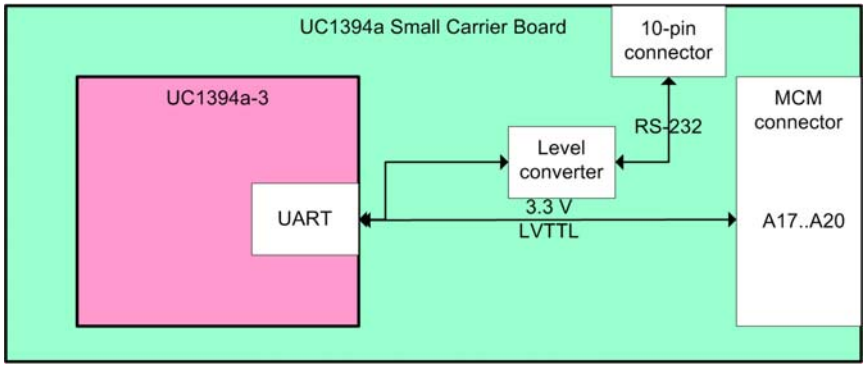


Figure 6: UART interface block diagram

The RS-232 signals are available on a 10-pin connector, located on the UV1394a Small Carrier board. The UART signals are also available on MCM connector A at 3.3V LVTTL. To convert to RS-232 an external level converter is required. For a connection example please refer to [14].

Signal	Connector	Cable connection to a remote PC	
	UC1394a Small Carrier 10-pin	Sub-D 9-pin	Sub-D 25-pin
TxD	5	2	3
RxD	3	3	2
RTS	4	8	5
CTS	8	7	4
GND	9, 10	5	7

Table 1: UART connector pin assignments

2.3.6 System Reset

.The reset input /RESETIN is connected to a pushbutton on the UC1394a Small Carrier. The required pull-up resistor is integrated in the MCM. The reset signals are described in [14].

Signal	MCM Connector pin
/RESETIN	A10
/RESETOUT	A9

Table 2: Reset signals

Please note that /RESETIN is driven for a short period of about 1µs in case of a software reset or watchdog reset.

2.3.7 JTAG Connector

The JTAG connector provides the JTAG signals of both, the CPU and the FPGA of the MCM. The JTAG interfaces are typically used with the respective download cables or emulators. For development kits, the carrier is shipped together with a JTAG adapter that provides suitable connectors for the download cables and emulators. Please refer to [14] for a description of the pinning of the JTAG connector.

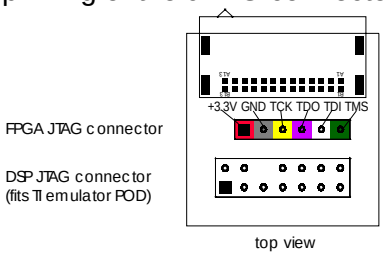


Figure 7: JTAG Adapter

The DSP JTAG interface is used for downloading and debugging DSP software. It is used with a JTAG emulator, such as the TI XDS series, which can be connected to the carrier board by an adapter. The JTAG adapter is included in the DCAM frame capture development kit.
Usually, the JTAG connector is used in conjunction with the JTAG adapter. This JTAG adapter provides connectors which are compatible with standard development tools:

- the Texas Instruments emulator cables, such as the XDS510 or compatible
- the Xilinx parallel download cable

The FPGA JTAG interface is used with programming hardware, such as the Xilinx parallel download cable. A JTAG adapter, which is included in the DCAM frame capture development kit, provides a suitable connector.
FPGA development for the MCM or the carrier board is available as a separate product.

2.3.8 Power Supply Input

The UC1394a-3 MCM requires a single, regulated 3.3 V power supply. The UC1394a Small Carrier generates this voltage.
The Power supply of the carrier can be provided by three different ways:

- From the DC power input socket (J7)
- From the IEEE1394 cable (over J8 or J9)
- Over the direct MCM connectors (J1, J2; requires modification of the carrier)

For a detailed description of the power supply please refer to [18].

2.3.9 TMS320VC5501/5502 Peripherals

The signals of the DSP peripherals HPI, GPIO, McBSPs, I2C, Timers etc. are directly routed to the MCM connectors of the UC1394a Small Carrier. For a detailed description of these interfaces please refer to [14].

3 Getting Started

Usually, the UC1394a-3 DSP Master BSP comes as a kit, including documentation and quick start examples. This chapter describes the first steps when using the DCAM frame capture development kit.

3.1 Required items:

- a development PC
- a JTAG emulator, from Texas Instruments (e.g. XDS510) or from another vendor
- Code Composer Studio (CCS) from Texas Instruments, version 3.1 or higher
- UC1394a Small Carrier or another suitable power supply
- optional: a terminal program, such as Hyperterminal and a RS-232 cable

3.2 Download procedure:

- connect the kit to the development PC using the JTAG emulator and the RS-232 cable (optional)
- for *Camera* and *OperateTool*: connect the digital camera to the kit, using the IEEE1394 cable.
- power on the system
- start Code Composer Studio
- select the "Load GEL..." command from the "File" menu
- locate *uc1394a-3master.gel* from the *GEL* folder on the distribution media and open it
- select the "Initialization"->"CPU_reset_and_init_300" command from the "GEL" menu
- select the "Load Program..." command from the "File" menu
- locate one of the application examples from the examples folder on the distribution media and open it (e.g. *toggle_led.out*)
- select the "Run" command from the "Debug" menu

Please note: the application examples do not use the usual *printf* function. Instead, where necessary, output is sent over the RS-232 interface (using 115200 baud and RTS/CTS handshake). This allows to store the examples in flash memory and then to execute them without the JTAG emulator. Before running applications using the RS-232 interface a Hyperterminal should be startet on the PC.

3.3 Debugging Software Using a JTAG Emulator

Select the "Halt" command from the "Debug" menu. CCS will stop the DSP from toggling the LED and it displays the current instruction in the disassembly window and in the source code window. Now you can use all debugging features that CCS provides, such as breakpoints, single stepping, and so on. For details, please refer to the CCS on-line help and documentation.

3.4 How to Store an Application in Flash Memory

The UC1394a-3 supports up to 832KB of flash memory for application code. This application code must be in a format suitable for the processor's boot loader. To generate such a file, the projects on the distribution CD contain a final build step that uses the hex55 utility. To program your application into the UC1394a's flash memory, you must

- connect the JTAG emulator to the UC1394a-3.
- start Code Composer Studio.
- open your project.
- build the project as normal.
- select the "Initialization" → "CPU_reset_and_init" command from the "GEL" menu.
- start the FlashBurn utility.
- the *FlashBurn* utility starts up with an empty window.
- select the "New" command from the "File" menu.
- click on the "Browse..." button right of "File To Burn".
- locate the application code that is to be programmed, e.g. *asynctst.hex* and open it.
- click on the "Browse..." button right of "FBTC Program File".
- locate *FBTCOrsysUC1394a-3.out* (the Flash Burn Target Component, usually in a folder named *FlashBurn* on the distribution media) and open it.
- select the "Save As..." command from the File menu.
- select a convenient location an and appropriate name for this configuration an save it.
- select the "Download FBTC" command from the "Program" menu.
- *FlashBurn* downloads the target component to the UC1394a-3.
- if *FlashBurn* still displays "Not connected",
  - change to Code Composer Studio,
  - select the "Initialization" → "CPU_reset_and_init" command from the "GEL" menu,
  - select the "Reload Program" command from the "File" menu,
  - select the "Run" command from the "Debug" menu
  - Now Code Composer Studio must display the cursor at *DoMessageProc* in the disassembly window.
- select the "Erase Flash" command from the "Program" menu.
- the erase process takes about 8..12 seconds to complete.
- select the "Program Flash" command from the "Program" menu.
- wait until the programming process is completed.
- now your application is programmed to flash memory and will boot at the next system start.

Further help can be found in the help menu of Code Composer Studio. The *FlashBurn* utility is included in the Orsys distribution.

4 Programming the UC1394a-3

This chapter describes the software programming interfaces of the UC1394a-3. It is intended for programmers who want develop their own, customized software to run on the UC1394a-3.
The UC1394a-3 provides the following programming interfaces:

- DCAM API
- register-level programming of the (BSP-specific) FPGA peripherals
- on-chip peripherals of the TMS320VC5501/5502

Programming the FPGA peripherals is described in [15]. Programming the on-chip DSP peripherals is supported on register level by the provided header files or by the chip support library, which is part of Code Composer Studio.

4.1 Required Tools

- TI Code Composer Studio V3.1 or higher
- SDS FlashBurn Utility (part of Orsys distribution)
- JTAG Emulator for program download, such as TI XDS510 or other products

4.2 Software Development Flow

User defined software can be written as C-source code. The source code modules are compiled by the C-compiler. The resulting object files must be linked with at least the runtime library for the TMS320VC5501/5502 (`rts55x.lib`). Usually, one or more object libraries are added during the linker process, such as the IEEE1394 API libraries and the module support library. The output of the linker is an executable file, which can be downloaded to the UC1394a-3 over the JTAG interface using an emulator. To store the user application permanently in flash memory, the .out file must be converted to a boot data stream by the hex conversion tool. To program this boot data stream, the FlashBurn utility must be started. The FlashBurn utility

- loads the Target Component (FBTCOrsysUC1394a-3.out) executable to the UC1394a-3 and starts it
- sends the boot data stream to the FBTC55, which in turn programs it to the flash memory.

Further details on flash programming can be found in chapter 3.4.
This development flow is shown in the picture below. The distribution media contains some project examples which perform this development flow.

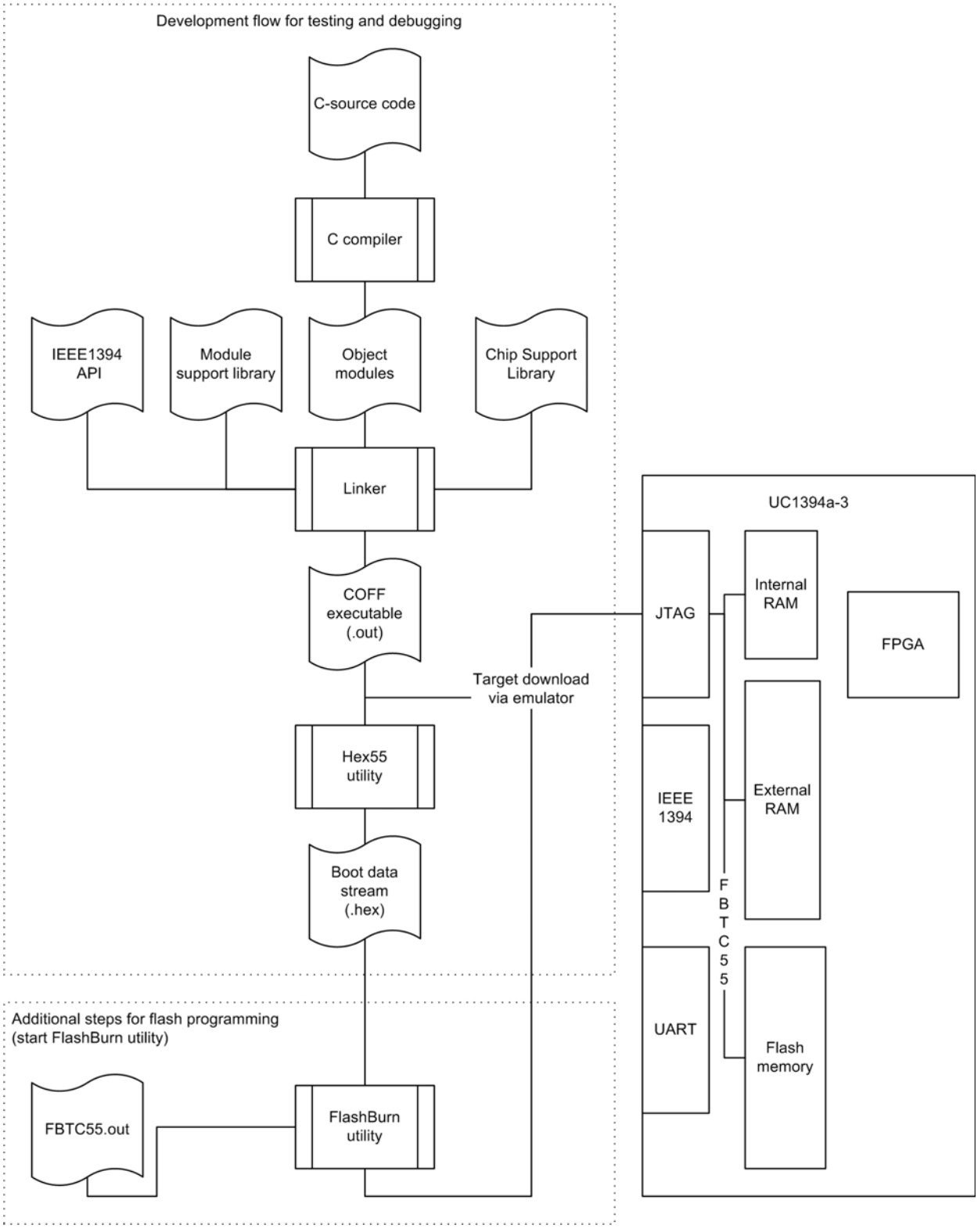


Figure 8: Software development flow

4.3 Startup Procedure

After power-up or a system reset, the DSP starts its internal boot loader. The boot loader initializes the MCM according to the information of the boot header. Then, it loads the application from flash memory into the internal RAM and starts program execution at the specified address. This is the

default startup procedure in end-system environment. During development the startup procedure looks a little bit different:
After power-up or a system reset, the DSP starts its internal boot loader. The boot loader tries to load an application from flash, which may succeed or leave the DSP in an unknown state. The user starts Code Composer Studio, loads UC1394a-3.GEL and puts the DSP to an initialized state by selecting the *CPU_reset_and_init* command from the "GEL" → "Initialization" menu. Now the user application can be loaded, executed and debugged using the emulator.

4.4 Hints for Programming the TMS320VC5501/5502

4.4.1 A Byte is 16 Bits

Please note, that these DSPs can only access data in units of 16 bit. Even a character array will consist of 16 bit. The screenshots below illustrate this.

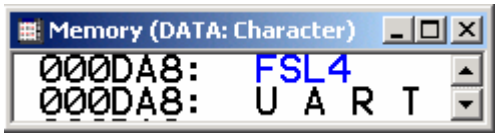


Figure 9: Memory view of a string in character format

Figure 10: Memory view of a string in binary format

Further information can be found in [7]; chapter "Memory and I/O space" and in [11]; chapter "Data types"

4.4.2 64K Page Limit

The TMS320C5000 series of DSPs use a 16-bit architecture, which adds restrictions to pointer accesses. Although the DSP as well as the C-compiler support 23-bit pointers, pointer manipulation is always done modulo 64K. Below is a code example that shows how to handle arrays which cross 64K boundaries.

```
/* wrong, will stay in the lower 64K bytes */
static int array[100000];
int i;
for (i = 0; i < sizeof(array); i++)
    array[i] = 0;

/* correct: use a cast to calculate the pointer for each access */
static int array[100000];
unsigned long i;
for (i = (unsigned long)array;
     i < (unsigned long array) + sizeof(array);
     i++)
    *(unsigned long *)i = 0;
```

4.4.3 Pipeline

Accesses to memory may take some clock cycles until they are completed, since the execution is broken down into several pipelined steps. For memory accesses this is no problem. However, accesses to hardware registers can lead to unexpected results. One example is disabling interrupts:

```
    asm(" BSET INTM");
    asm(" NOP");
    asm(" NOP");
    asm(" NOP");
    asm(" NOP");
    asm(" NOP");
    asm(" NOP");
```

Without the NOP instruction, an interrupt can occur immediately after the BSET INTM instruction. The execution of the NOPs ensures, that all stages of the BSET INTM instruction have been performed before further code is executed. The NOPs must be inserted only if the code immediately following the BSET INTM instruction must be protected against interrupts.

Another point is access to peripherals in a write-read back fashion. Since a write access takes longer to be performed than a read access, the read may occur before the write, resulting in outdated data. When reading back data that has just been written, two NOP instructions should be inserted between write and read. Below is an example taken from the flash programming routines:

```
/* Wrong, do not use that */
    for (ulWords = 0; ulWords < ulLengthInWords; ulWords++)
    {
        // enter programming mode
        *(volatile INT16U*) (UC1394A3_FLASH_BASE + 0x0555) = 0xAA;
        *(volatile INT16U*) (UC1394A3_FLASH_BASE + 0x02AA) = 0x55;
        *(volatile INT16U*) (UC1394A3_FLASH_BASE + 0x0555) = 0xA0;
........// write data word to flash
        *(volatile INT16U*)ulFlashAdr = *(volatile INT16U*)ulDataAdr;
........// wait until programmed
        while (*(volatile INT16U*)ulFlashAdr != *(volatile INT16U*)ulDataAdr)
            asm(" NOP");
        ulFlashAdr++;
        ulDataAdr++;
        if ((ulWords & FLASH_PRG_CALLBACK_RATIO) == 0 &&
            pCallback != NULL)
            pCallback();
    }

/* corrected code */
    for (ulWords = 0; ulWords < ulLengthInWords; ulWords++)
    {
        // enter programming mode
        *(volatile INT16U*) (UC1394A3_FLASH_BASE + 0x0555) = 0xAA;
        *(volatile INT16U*) (UC1394A3_FLASH_BASE + 0x02AA) = 0x55;
        *(volatile INT16U*) (UC1394A3_FLASH_BASE + 0x0555) = 0xA0;
........// write data word to flash
        *(volatile INT16U*)ulFlashAdr = *(volatile INT16U*)ulDataAdr;
        // The following NOP's causes the write operation to finish before
        // the programming status is read. Otherwise, the pipeline could
        //  exchange write and read, which causes a premature abort.
        asm(" NOP");
        asm(" NOP");
........// wait until programmed
        while (*(volatile INT16U*)ulFlashAdr != *(volatile INT16U*)ulDataAdr)
            asm(" NOP");
        ulFlashAdr++;
        ulDataAdr++;
        if ((ulWords & FLASH_PRG_CALLBACK_RATIO) == 0 &&
            pCallback != NULL)
            pCallback();
    }
```

5 Application Examples

The distribution media contains two kinds of application examples:

- Examples that use the DCAM API
- Examples from the DSP master BSP

The examples using the DCAM API are described in [17]. All other examples are described in the subsequent sections. All examples can be downloaded to the kit by using a JTAG emulator or they can be programmed to the MCM's flash memory as described in chapter 3.4. To download an application example to the MCM, please proceed as follows:
Required items:

- a development PC, with the software listed below installed.
- Texas Instruments Code Composer Studio (CCS) V2.2*x.* A run time limited version is downloadable from www.ti.com.
- a JTAG emulator
- a terminal program, such as Hyperterminal, which is usually part of Windows distributions
- a DCAM frame capture development kit, including a JTAG adapter, all cables and a suitable power supply
- a digital camera for DCAM API examples

All application examples are provided as a CCS project. The project has two available configurations: Debug and Release. Debug is the default configuration and should be used during development. The Release configuration differs from Debug in two points:

- no debugging symbols are created, the code is not suitable for source code debugging, but better optimized
- The Release version of the module support library is used

The Release configuration should be used for the final application after development is finished. Further, all example projects contain a final build step that creates a *.hex* file. This file can be programmed to flash memory as described in chapter 3.4.

5.1 Download procedure

- connect the kit to the development PC using the JTAG emulator / JTAG adapter and the RS-232 cable
- for *Camera* and *Operate Tool*: connect the digital camera to the kit, using the IEEE1394 cable.
- power on the system
- start Code Composer Studio
- select the "Load GEL..." command from the "File" menu
- locate *uc1394a-3_master_bsp.gel* from the *GEL* folder on the distribution media and open it
- select the "Initialization"->"CPU_reset_and_init_300Mhz" command from the "GEL" menu
- select the "Load Program..." command from the "File" menu
- locate one of the application examples from the examples folder on the distribution media and open it (e.g. *toggle_led.out*)
- select the "Run" command from the "Debug" menu

Please note: the application examples do not use the usual *printf* function. Instead, where necessary, output is sent over the UART interface (using 115200 baud and RTS/CTS handshake). This allows to store the examples in flash memory and then to execute them without the JTAG emulator.

*5.2 LED Control (*toggle_led*)*

This is the most basic application example. It initializes the MCM and then enters a main loop. The main loop just toggles the MCM's LED. After loading and starting this example. the MCM's LED is blinking. This application example can be used as a rudimentary test to check if the kit and the MCM are working properly.

*5.3 UART (*hello*)*

This example shows how to program the UART of the DSP using driver functions from the module support library. First, the MCM is set up. Then, the UART is initialized for 115200 baud and hardware (RTS/CTS) handshake. Then, an output message is assembled using the *stdio* function *sprintf*. The output message contains some information about the MCM. The output message is sent to the RS-232. Finally, the main loop is entered. In the main loop, the UART interface is checked for incoming characters. Whenever a character comes in, it is simply echoed.

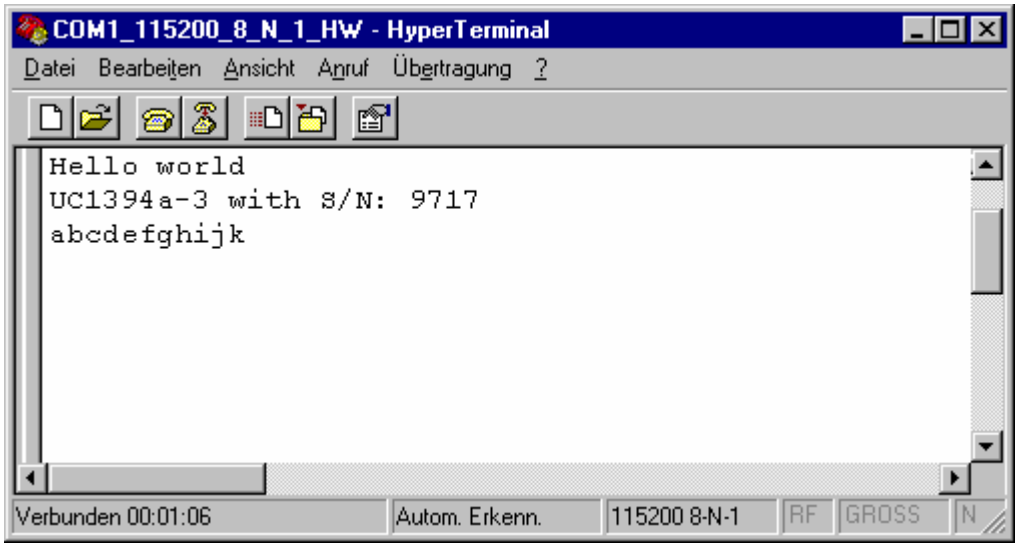


Figure 11: Sample session of the *hello* example

*5.4 Buffered Character I/O (*dbg_out*)*

This example uses the UART interface at a higher level of abstraction: buffered character I/O, as provided by the module support library, see chapter 6 for details. This is an alternative to using the *stdio* functions, such as *sprintf*, *sscanf*, etc. *dbg_out* prints out the same startup message as *hello*, but the main loop is programmed as a command interpreter. This shows how to implement an application that is interactively controlled over RS-232. Pressing the '?' key within the terminal program causes a help page to be displayed. Other command keys can easily be added by inserting appropriate case statement in the command switch. Below is an example that shows how insert a command that toggles the MCM LED by pressing the key 't':

```
    // below is a command switch that could be used in applications
    // that require user interaction over RS_232
    switch(c)
    {
    case '?':
    case 'h':
        DebugOutConstString("Debug interface example\r\n");
        DebugOutConstString("'h' and '?' show this help page\r\n"
                            "no other commands/keys defined\r\n");
        break;
    case 't':
        // toggle the red MCM LED
        UC1394A3_SYS_CTL ^= UC1394A_SYS_LED;
        break;
    default:
        DebugOutConstString("invalid command. "
                            "'?' shows a help page.\r\n");
        break;
    }
}
```

*5.5 Peripheral Interface (*periph_if*)*

This application example has neither any text output, nor does it control the LED. It is mainly intended as a source code example. Further, the peripheral interface signals can be viewed with an oscilloscope or a logic analyzer. The UC1394a-3 is initialized with the default settings, the peripheral interface is set to a burst size of 5 16-bit words and the interface timings are set to 1-1-1 (setup-strobe-hold).
Then the main loop performs the following sequence in an infinite loop:

- issue pulse on XF pin (can be used as a trigger signal)
- wait until the write FIFO has space for the next burst
- write 5 16-bit words to the peripheral interface
- trigger read burst (will be performed after write has completed)
- wait until read operation complete
- read data from read FIFO

Figure 12 shows the waveforms of the control signals /PER_CS, PER_R/W, /PER_STRB and data signal PER_D0 generated by each cycle of the main loop. The left side of the figure shows a write burst of 5 16-bit words, the rigth side shows the followed read burst of 5 16-bit words.

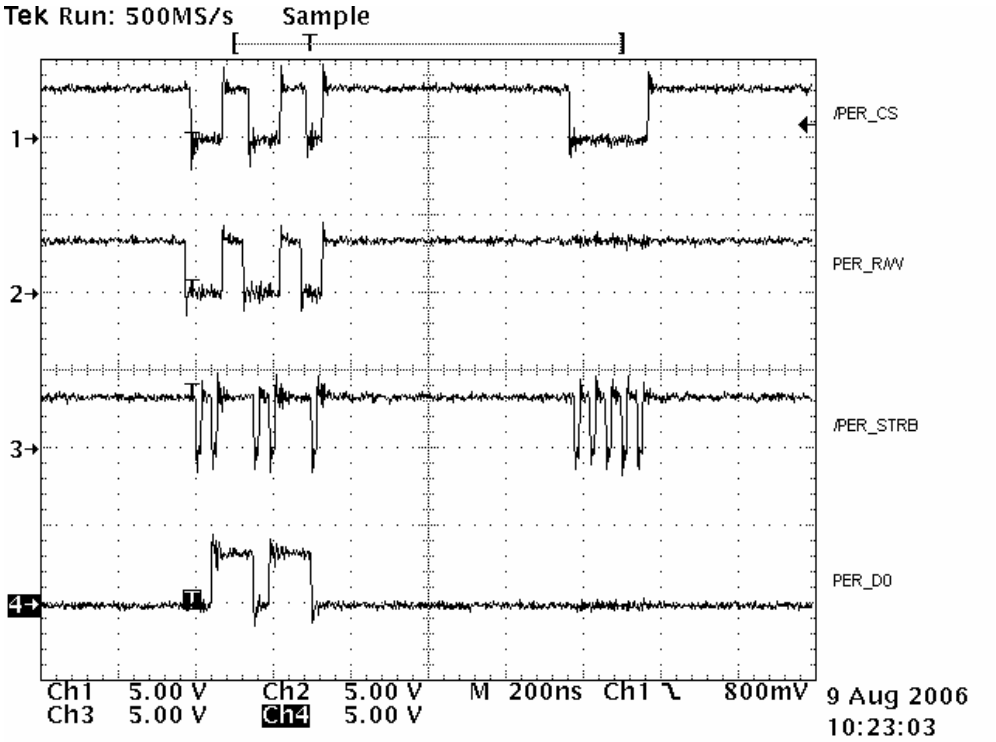


Figure 12: Waveforms generated by the *periph_if* example

Figure 13 shows the signals generated by a write burst of 5 16-bit words in a higher resolution than Figure 12. Data can be written to the write FIFO of the peripheral interface by 16-bit or 32-bit accesses. In this example the data is written to the FIFO by 2 x 32-bit and 1 x 16-bit accesses. 32-bit write accesses are faster than two consecutive 16-bit writes since two accesses (strobes) take place within one chip select cycle. The data written to the interface are counter values, that is PER_D0 toggles with each write access.

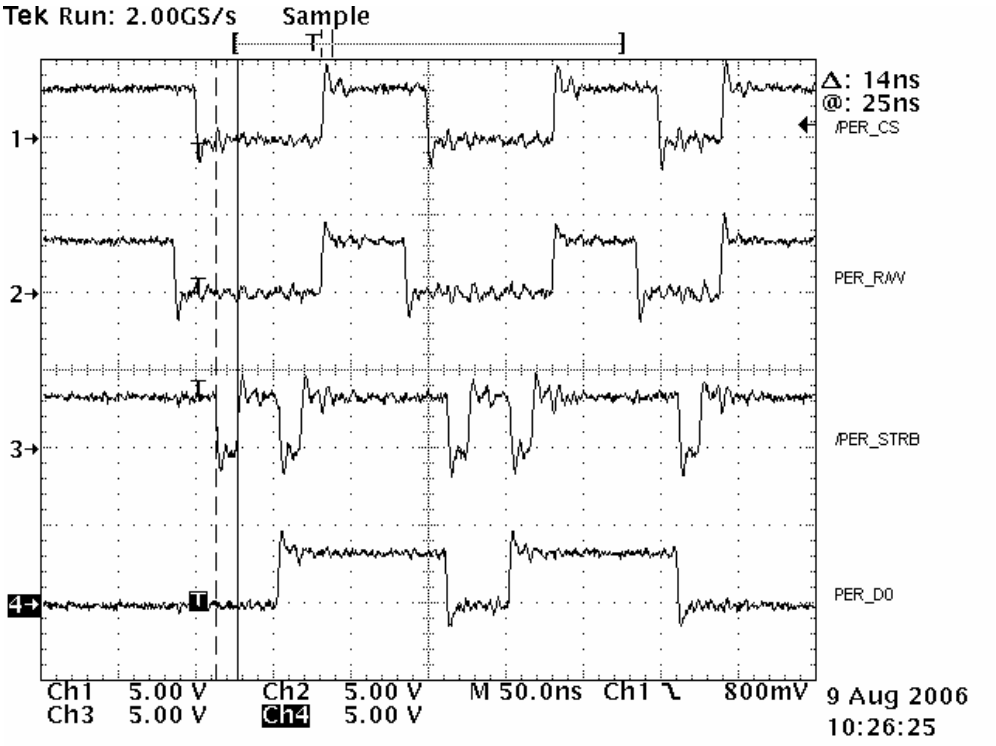


Figure 13: Waveforms generated by the *periph_if* example for a write burst

Figure 14 shows the signals generated by a read burst of 5 16-bit words in a higher resolution than Figure 12. Data can be read from the read-FIFO of the peripheral interface only by 32-bit accesses since the EMIF does not support 16-bit reads. In this example the data is read from the FIFO by 3 x 32-bit accesses. Read accesses are always executed as access bursts, that is multiple accesess (strobes) take place within one chip select cycle. The data words are dummy values, here PER_D0 remains low.

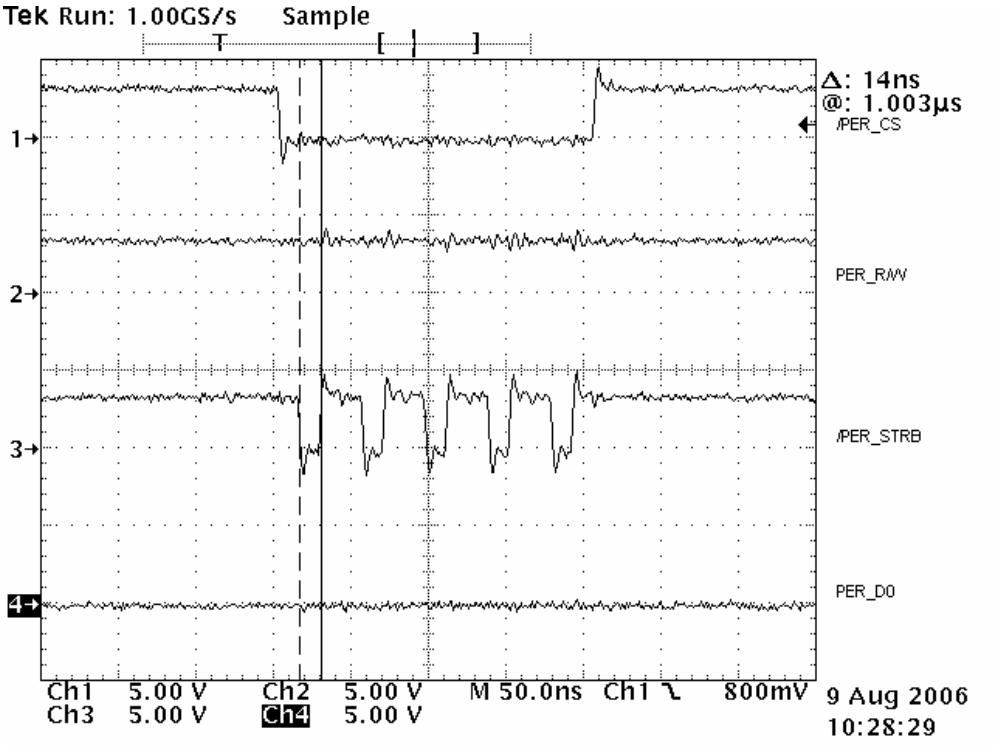


Figure 14: Waveforms generated by the *periph_if* example for a read burst

6 Module Support Library

The module support library is a collection of functions that are commonly used when programming the UC1394a-3 MCM. The code in this library is usually not changed by the user. During software development, this library is simply added to the project. However, the source code is provided for reference and for cases where a customization is necessary. A CCS project for creating the module support library is also provided. Please note: after compiling the library sources, the compiled libraries reside in the respective output directories (*Debug* and/or *Release*). For using them with the example projects, they must be copied to the *lib\Release* and *lib\Debug* directories.

6.1 Module Support Library Modules

The module support library contains the following modules:

Module	Contents
`Init.c`	module support functions
`fpgaload.c`	FPGA loader
`Uart.c`	UART routines
`flash.c`	flash programming routines
`debug.c`	simple, buffered I/O over the UART interface
`Hexutil.c`	binary to hexadecimal ASCII conversion
`Decutil.c`	binary to decimal ASCII conversion

Below is a brief description of each module. The functions of module are explained in chapter 6.5.

6.1.1 init.c

This module defines initialization and utility functions for the MCM, such as interrupt control.

6.1.2 fpgaload.c

This module contains a loader for FPGA code. The FPGA must be loaded using this loader at system startup. FPGA resources are only available after loading.

6.1.3 uart.c

This module contains functions to control the UART of the TMS320C5501/5502 DSP.

6.1.4 flash.c

Contains flash programming routines. It is recommended that application software does not modify the flash memory. Instead, the provided methods for accessing the flash memory should be used (*FlashBurn* utility for application code programming (see chapter 4.3) or FPGA flasher executable for updating / programming FPGA code).

6.1.5 debug.c

This module contains a simple system for buffered character I/O over the UART interface. Typically, the functions of this module are not used directly, but over associated macros (see chapter 6.4). *debug.c* can be used as an alternative for the *stdio* functions (e.g. *printf*), especially, when small code size is required or no emulator is available.

6.1.6 hexutil.c

Utility functions that convert binary values to hexadecimal ASCII.

6.1.7 decutil.c

Utility functions that convert binary values to decimal ASCII.

6.2 Module Support Library Header Files

msl.h	Contains function prototypes for the main part of the module support library, such as initialization and interrupt management.
master_bsp.h	Defines the FPGA registers and includes basic hardware definitions of the UC1394a-3 equipped with Master BSP.
fpgaload.h	functions for loading the FPGA.
debug.h	Defines a simple, buffered character I/O interface using the UART interface. Suitable for debugging output as well as general character I/O.

6.3 Global Variables Reference

6.3.1 Clock Rates

The variables below contain the clock rates of the DSP. The function *InitDSP* sets up the clock rates and then initializes the variables. These variables can be used to calculate software controlled timings.

Clock rates initialized by *InitDSP*:

```
INT32U ulSysclk1; // fast peripherals (DMA, HPI, Timer)
INT32U ulSysclk2; // slow peripherals (McBSP, I2C, UART)
INT32U ulSysclk3; // EMIF
INT32U ulClkout3; // CPU
```

6.3.2 Interrupt Vector Table

The module support library maintains an interrupt vector table. This table is initialized by *InitDSP*. User interrupt handlers can be inserted by calling *IntHook*. The table is accessible from outside of the module support library in order to better support debugging. Directly accessing the interrupt vector table should be avoided.

```
// interrupt vector table
extern struct
{
    void (*handler) (void);
    INT32U dummy;
} vectab[32];
```

6.4 Macros Reference

This chapter lists the macros that are defined by the module support library. Currently, the only available macros are utility functions for *debug.c* and macros to control the red LED of the UC1394a-3 MCM.

6.4.1 DebugOutByteHex

Converts a 8-bit number into a string (hexadecimal) and puts the string into the debug transmit buffer. This is a macro that calls the functions *HexByte2Ascii* and *DebugPuts*.

defined in
debug.h

synopsis

```
void DebugOutByteHex(INT8U digit);
```

parameters

digit	8-bit number to convert and put to the debug interface

return value
none

6.4.2 DebugOutConstString

Puts a string into the debug transmit buffer. This is a macro that calls the function *DebugPuts*. It is intended for constant string output , such as `DebugOutConstString("Hello, world\r\n");`. Pointers to strings will fail because the length of the string is not known at compile time.

defined in
debug.h

synopsis
```
INT16U DebugOutConstString(char cString[]);
```

parameters
cString[] output string for the debug interface

return value
number of characters actually written

6.4.3 DebugOutDwordHex

Converts a 32-bit number into a string (hexadecimal) and puts the string into the debug transmit buffer. This is a macro that calls the functions *HexLong2Ascii* and *DebugPuts*.

defined in
debug.h

synopsis
```
void DebugOutDwordHex(INT32U digit);
```

parameters
digit 32-bit number to convert and put to the debug interface

return value
none

6.4.4 DebugOutNibbleHex

Converts a 4-bit number (lower 4 bits of 8-bit number) into a string (hexadecimal) and puts the string into the debug transmit buffer. This is a macro that calls the functions *HexNibble2Ascii* and *DebugPuts*.

defined in
debug.h

synopsis
```
void DebugOutNibbleHex(INT8U digit);
```

parameters
digit 8-bit number to convert and put to the debug interface

return value
none

6.4.5 DebugOutSByteDec

Converts a signed 8-bit number into a string of 4 characters and puts the string into the debug transmit buffer. This is a macro that calls the functions *DecSignedByte2Ascii* and *DebugPuts*.

defined in
debug.h

synopsis
```
void DebugSByteDec(INT8S digit);
```

parameters
digit number to convert and put to the debug interface

return value
none

6.4.6 DebugOutSDwordDec

Converts an signed 32-bit number into a string of 11 characters and puts the string into the debug transmit buffer. This is a macro that calls the functions *DecSignedDword2Ascii* and *DebugPuts*.

defined in
debug.h

synopsis
```
void DebugOutsDwordDec(INT32S digit);
```

parameters
digit number to convert and put to the debug interface

return value
none

6.4.7 DebugOutSNibbleDec

Converts a signed 4-bit number into a string of two characters and puts the string into the debug transmit buffer. This is a macro that calls the functions *DecSignedNibble2Ascii* and *DebugPuts*.

defined in
debug.h

synopsis
```
void DebugOutSNibbleDec(INT8S digit);
```

parameters
digit number to convert and put to the debug interface

return value
none

6.4.8 DebugOutString

Puts a string into the debug transmit buffer. This is a macro that calls the function *DebugPuts*. Pointers to strings are allowed since the length of the string is determined at run time.

defined in
debug.h

synopsis
```
INT16U DebugOutString(char *pString);
```

parameters
pString pointer to output string for debug the interface

return value
number of characters actually written

6.4.9 DebugOutSWordDec

Converts a signed 16-bit number into a string of 6 characters and puts the string into the debug transmit buffer. This is a macro that calls the functions *DecSignedWord2Ascii* and *DebugPuts*.

defined in
debug.h

synopsis
```
void DebugOutSWordDec(INT16S digit);
```

parameters
digit number to convert and put to debug the interface

return value
none

6.4.10 DebugOutUByteDec

Converts an unsigned 8-bit number into a string of 3 characters and puts the string into the debug transmit buffer. This is a macro that calls the functions *DecUnsignedByte2Ascii* and *DebugPuts*.

defined in
debug.h

synopsis
```
void DebugOutUByteDec(INT8U digit);
```

parameters
digit number to convert and put to the debug interface

return value
none

6.4.11 DebugOutUDwordDec

Converts an unsigned 32-bit number into a string of 10 characters and puts the string into the debug transmit buffer. This is a macro that calls the functions *DecUnsignedDword2Ascii* and *DebugPuts*.

defined in
debug.h

synopsis
```
void DebugOutUDwordDec(INT32U digit);
```

parameters
digit number to convert and put to the debug interface

return value
none

6.4.12 DebugOutUNibbleDec

Converts an unsigned 4-bit number into a string of two characters and puts the string into the debug transmit buffer. This is a macro that calls the functions *DecUNibble2Ascii* and *DebugPuts*.

defined in
debug.h

synopsis
```
void DebugOutUNibbleDec(INT8U digit);
```

parameters
digit number to convert and put to the debug interface

return value
none

6.4.13 DebugOutUWordDec

Converts an unsigned 16-bit number into a string of 5 characters and puts the string into the debug transmit buffer. This is a macro that calls the functions *DecUnsignedWord2Ascii* and *DebugPuts*.

defined in
debug.h

synopsis
```
void DebugOutUWordDec(INT16U digit);
```

parameters
digit number to convert and put to the debug interface

return value
none

6.4.14 DebugOutWordHex

Converts a 16-bit number into a string (hexadecimal)) and puts the string into the debug transmit buffer. This is a macro that calls the functions *HexWord2Ascii* and *DebugPuts*.

defined in
debug.h

synopsis
```
void DebugOutWordHex(INT16U digit);
```

parameters
digit 16-bit number to convert and put to the debug interface

return value
none

6.4.15 **UC1394A3_LED_ON**

Turns the red LED of the UC1394a-3 MCM on. Defined in *uc1394a-3.h.*

6.4.16 **UC1394A3_LED_OFF**

Turns the red LED of the UC1394a-3 MCM off. Defined in *uc1394a-3.h.*

6.4.17 **UC1394A3_LED_TOGGLE**

Toggles the red LED of the UC1394a-3 MCM. Defined in *uc1394a-3.h.*

6.5 Functions Reference

This chapter gives a brief description of the module support library functions.

6.5.1 InitDSP

Configures the DSP to work with the peripherals. Sets up processor clock and EMIF settings. Sets up and initializes the interrupt vector table. Interrupts are disabled globally during initialization an are enabled again when *InitDSP* returns. Further, all maskable interrupts are disabled and cleared. Interrupt vectors are set up to a table managed by the module support library. The interrupt vector table is initialized with dummy interrupt handlers (*DefaultISRx()*) in order to get deterministic behavior when uninitialized interrupts are triggered.

defined in
msl.h

synopsis
```
void InitDsp(INIT_MODE eMode);
```

parameters
none

return value
none

6.5.2 IntHook

defined in

msl.h

Description
Installs an interrupt handler for the given interrupt number in the interrupt vector table. The interrupt numbers are defined in *c5501.h*. The interrupt handler must be defined with the `interrupt` keyword.

synopsis
```
void IntHook (int iIntNumber, void (*pHandler)(void));
```

parameters
int iIntNumber number of interrupt to be inserted
pHandler pointer to the interrupt handler

return value
none

6.5.3 IntEnable

Enables the specified interrupt in the corresponding Interrupt Enable Register. The interrupt numbers are defined in *c5501.h*.

defined in
msl.h

synopsis
```
void IntEnable (int iIntNumber)
```

parameters
int iIntNumber number of interrupt to be enabled

return value
none

6.5.4 IntDisable

Disables the specified interrupt in the corresponding Interrupt Enable Register. The interrupt numbers are defined in *c5501.h*.

defined in
msl.h

synopsis
```
void IntDisable (int iIntNumber)
```

parameters
int iIntNumber number of interrupt to be disabled

return value
none

6.5.5 IntClear

Clears the specified interrupt in the corresponding Interrupt Flag Register if pending. The interrupt numbers are defined in *c5501.h*.

defined in
msl.h

synopsis
```
void IntClear (int iIntNumber)
```

parameters
iIntNumber number of interrupt to be cleared (see c5501.h)

return value
none

6.5.6 FpgaLoad

Loads code to the FPGA (usually from flash memory). Default address when loading the FPGA code from flash is `UC1394A3_FLASH_FPGA_CODE`. The code length can be retrieved from the code's header by specifying `UC1394A3_FLASH_FPGA_LENGTH`. When the FPGA code is linked to the application, the parameters must be modified accordingly. Please note: The FPGA code is usually preceded by a header. *FpgaLoad()* supports both, code with and without header. Care must be taken to specify the correct length for each variant. The length is of the header is 28 bytes for each variant.

defined in
fpgaload.h

synopsis
```
int FpgaLoad(INT32U *pData, INT32U ulLength);
```

parameters
pData pointer to FPGA image in flash memory
ulLength length of FPGA image in bytes

return value
`FPGA_SUCCESS` (zero) if FPGA image is loaded successfully, otherwise the FPGA has not been loaded. Possible reasons for this are:
the flash area for FPGA code is not programmed or contains invalid data
the FPGA Code was created for a non-matching device
the FPGA Code was created with incorrect programming file options.

6.5.7 FlashGetDeviceInfo

Reads manufacturer and device ID from the flash and stores them in the specified locations. Default manufacturer ID is 0001_{16} (AMD). Default device ID is $22BA_{16}$ (29LV800).

defined in
msl.h

synopsis
```
void FlashGetDeviceInfo(INT16U *pManufacturer, INT16U *pDevice, void (*pCallback)(void));
```

parameters
pManufacturer pointer to location where manufacturer ID is stored
pDevice pointer to location where device ID is stored

return value
None

6.5.8 FlashEraseSector

Erases the specified sector. During the erase process, a user-specified callback function is executed to allow the application to continue processing or to indicate the progress of the operation. The callback is called whenever the erase status is queried. Since the flash memory is completely used for storing application and FPGA code (see chapter "Flash Memory" in [14]), application software should not modify the flash contents.

defined in
msl.h

synopsis
```
void FlashEraseSector(int iSector, void (*pCallback)(void));
```

parameters

iSector	Sector number to be erased. Allowed values: 0 .. 15.
pCallback	Pointer to a user callback function. Must be set to a valid user callback function or to NULL if no callback is used.

return value

FLASH_OK	Operation was successful

6.5.9 FlashProgram

Programs data into a previously erased area. During programming, a user-specified callback function is executed to allow the application to continue processing or to indicate the progress of the operation. The callback is called each time when 100 words have been programmed to the flash. After programming, the programmed data is verified.

defined in
msl.h

synopsis
```
int FlashProgram(INT32U ulStartOffset, INT32U ulLengthInWords, INT16U *pusData,
                 void (* pCallback)(void));
```

parameters

ulStartOffset	Destination offset relative to start of the flash, specified in 16-bit words. Allowed values: 00000000_{16} ... $000C0000_{16}$, or one of UC1394A3_FLASH_SA0_OFFS ... UC1394A3_FLASH_SA15_OFFS.
ulLengthInWords	Number of 16-bit words to program.
pusData	Points to the source data.
pCallback	User callback function.

return value

FLASH_OK	Programming was successful.
FLASH_COMPARE_ERROR	Verification of the programmed data failed.

6.5.10 DebugBufmgr

Writes one character form the debug transmit buffer to the debug interface if there is data in the transmit buffer and the underlying debug interface is ready to accept it.
Reads one character from the debug interface to the debug receive buffer if data is available and the buffer is not already full.
The function doesn't operate interrupt-driven, so it must be called periodically.

defined in
debug.h

synopsis
```
void DebugBufmgr(void);
```

parameters
none

return value
none

6.5.11 DebugFlush

Flushes the debug transmit buffer. The function just calls *DebugBufmgr* as long as the debug transmit buffer is not empty.

defined in
debug.h

synopsis
```
void DebugFlush(void);
```

parameters
none

return value
none

6.5.12 DebugGetc

Reads one character from the debug receive buffer.

defined in
debug.h

synopsis
```
int DebugGetc(void);
```

parameters
none

return value
character read from the debug receive buffer or *DEBUG_EOF* if buffer is empty

6.5.13 DebugGets

Gets a debug message from the debug receive buffer.
The debug receive buffer is read until:
a) a newline character (\n) is encountered
b) a carriage return character (\r) is encountered
c) a null-character ('\0') is encountered
d) *usMaxLen* - 1 characters are read
e) buffer is empty

defined in
debug.h

synopsis
```
unsigned short DebugGets(unsigned short usMaxLength, char *pDebugText);
```

parameters

usMaxlength	maximum size of the debug message with trailing '\0'
pDebugText	pointer to debug message.

return value
number of actually read characters.

6.5.14 DebugInit

Initializes the debug interface and the UART.

defined in
debug.h

synopsis
```
void DebugInit(void);
```

parameters
none

return value
none

6.5.15 DebugKbhit

Tests, whether the debug receive buffer is empty.

defined in
debug.h

synopsis
```
BOOL DebugKbhit(void);
```

parameters
none

return value

TRUE	there is at least one character in the debug receive buffer
FALSE	debug receive buffer is empty

6.5.16 DebugPutc

Puts one character into the debug transmit buffer.

defined in
debug.h

synopsis
```
INT8U DebugPutc(char c);
```

parameters

c	output character for debug interface

return value
number of characters actually written (0 or 1)

6.5.17 DebugPuts

Puts a message into the debug transmit buffer.

defined in
debug.h

synopsis
```
INT16U DebugPuts(unsigned short usLength, char *pDebugText);
```

parameters

usLength	number of characters in debug string (without trailing '\0')
pDebugText	pointer to debug message

return value
number of characters actually written

6.5.18 DecSignedByte2Ascii

Converts a signed 8 bit number into a character string in decimal ASCII representation. The Character string consists of 4 characters, starting with either <space> for positive numbers or '-' for negative numbers. The string contains leading zeros if the absolute value is less than 100.

defined in
decutil.h

synopsis
```
void DecSignedByte2Ascii(INT8S digit, char *pResult);
```

parameters

digit	number to be converted
pDebugText	pointer to storage for the converted string

return value
none

6.5.19 DecSignedDword2Ascii

Converts a signed 32 bit number into a character string in decimal ASCII representation. The Character string consists of 11 characters, starting with either <space> for positive numbers or '-' for negative numbers. The string contains leading zeros if the absolute value is less than 1000000000.

defined in
decutil.h

synopsis
```
void DecSignedDword2Ascii(INT32S digit, char *pResult);
```

parameters

digit	number to be converted
pDebugText	pointer to storage for the converted string

return value
none

6.5.20 DecSignedNibble2Ascii

Converts a signed 4 bit number into a character string in decimal ASCII representation. The Character string consists of 2 characters, starting with either <space> for positive numbers or '-' for negative numbers.

defined in
decutil.h

synopsis
```
void DecSignedNibble2Ascii(INT8U digit, char *pResult);
```

parameters

digit	number to be converted
pDebugText	pointer to storage for the converted string

return value
none

6.5.21 DecSignedWord2Ascii

Converts a signed 16 bit number into a character string in decimal ASCII representation. The Character string consists of 6 characters, starting with either <space> for positive numbers or '-' for negative numbers. The string contains leading zeros if the absolute value is less than 10000.

defined in
decutil.h

synopsis
```
void DecSignedWord2Ascii(INT16S digit, char *pResult);
```

parameters

digit	number to be converted
pDebugText	pointer to storage for the converted string

return value
none

6.5.22 DecUnsignedByte2Ascii

Converts an unsigned 8 bit number into a character string in decimal ASCII representation. The Character string consists of 3 characters and contains leading zeros if the result is less than 100.

defined in
decutil.h

synopsis
```
void DecUnsignedByte2Ascii(INT8U digit, char *pResult);
```

parameters

digit	number to be converted
pDebugText	pointer to storage for the converted string

return value
none

6.5.23 DecUnsignedDword2Ascii

Converts an unsigned 32 bit number into a character string in decimal ASCII representation. The Character string consists of 10 characters and contains a leading zero if the result is less than 1000000000.

defined in
decutil.h

synopsis
```
void DecUnsignedDword2Ascii(INT32U digit, char * pResult)
```

parameters

digit	number to be converted
pDebugText	pointer to storage for the converted string

return value
none

6.5.24 DecUnsignedNibble2Ascii

Converts an unsigned 4 bit number into a character string in decimal ASCII representation. The Character string consists of 2 characters and contains a leading zero if the result is less than 10.

defined in
decutil.h

synopsis
```
void DecUnsignedNibble2Ascii(INT8U digit, char *pResult);
```

parameters

digit	number to be converted
pDebugText	pointer to storage for the converted string

return value
none

6.5.25 DecUnsignedWord2Ascii

Converts an unsigned 16 bit number into a character string in decimal ASCII representation. The Character string consists of 5 characters and contains leading zeros if the result is less than 10000.

defined in
decutil.h

synopsis
```
void DecUnsignedWord2Ascii(INT16U digit, char *pResult);
```

parameters

digit	number to be converted
pDebugText	pointer to storage for the converted string

return value
none

6.5.26 HexByte2Ascii

Converts a 8 bit number into a string ("00".."FF").

defined in
hexutil.h

synopsis
```
void HexByte2Ascii(unsigned char ucNum, char *pResult);
```

parameters

ucNum	8 bit number to convert
pResult	Pointer to result. Must be at least 3 bytes.

return value
none

6.5.27 HexDword2Ascii

Converts a 32-bit number into a string ("00000000.."FFFFFFFF").

defined in
hexutil.h

synopsis
```
void HexDword2Ascii(unsigned long ulNum, char *pResult);
```

parameters

ulNum	32 bit number to convert
pResult	Pointer to result. Must be at least 9 bytes.

return value
none

6.5.28 HexNibble2Ascii

Converts a 4-bit number (lower 4 bits of 8 bit number) into a string ("0.."F").

defined in

hexutil.h

synopsis
```
void HexNibble2Ascii(const INT8U digit, char *pResult);
```

parameters

digit	8 bit number to convert
pResult	Pointer to result. Must be at least 2 bytes.

return value
none

6.5.29 HexWord2Ascii

Converts a 16-bit number into a string ("0000".."FFFF").

defined in
hexutil.h

synopsis
```
void HexWord2Ascii(INT16U  usNum, char *pResult);
```

parameters

usNum	16 bit number to convert
pResult	Pointer to result. Must be at least 5 bytes.

return value
none

6.5.30 UartClearRts

Signals 'no-request-to-send' on the RTS line. The RTS line must be controlled by application software if it was enabled by the call to `UartInit`.

defined in
msl.h

synopsis
```
void UartClearRts (void);
```

parameters
none

return value
none

6.5.31 UartClearToSend

Check if remote device can accept a character, that is the /CTS line is active (low). Then a character may be sent to the remote device.

defined in
msl.h

synopsis
```
INT16U UartClearToSend (void);
```

parameters
none

return value
1, remote device is 'clear-to-send', that is a character may be sent
0, remote device is 'not-clear-to-send', that is if character is sent it will be lost

6.5.32 UartDisableLinestatInt

Disables the receiver line status interrupt.

defined in
msl.h

synopsis
```
void UartDisableLinestatInt(void);
```

parameters
none

return value
none

6.5.33 UartDisableRxInt

Disables the receiver data-ready and the receiver timeout interrupt.

defined in
msl.h

synopsis
```
void UartDisableRxInt(void);
```

parameters
none

return value
none

6.5.34 UartDisableTxInt

Disables the transmit holding register empty interrupt.

defined in
msl.h

synopsis
```
void UartDisableTxInt(void);
```

parameters
none

return value
none

6.5.35 UartEnableLinestatInt

Enables the receiver line status interrupt. Multiple interrupts cause the interrupt to stay asserted, so the interrupt handler must check all possible interrupt sources.

defined in
msl.h

synopsis
```
void UartEnableLinestatInt(void);
```

parameters
none

return value
none

6.5.36 UartEnableRxInt

Enables the receiver data-ready and the receiver timeout interrupt. Multiple interrupts cause the interrupt to stay asserted, so the interrupt handler must check all possible interrupt sources.

defined in
msl.h

synopsis
```
void UartEnableRxInt(void);
```

parameters
none

return value
none

6.5.37 UartEnableTxInt

Enables the transmit holding register empty interrupt. Multiple interrupts cause the interrupt to stay asserted, so the interrupt handler must check all possible interrupt sources.

defined in
msl.h

synopsis
```
void UartEnableTxInt(void);
```

parameters
none

return value
none

6.5.38 UartInit

Initializes the UART of the DSP.

defined in
msl.h

synopsis
```
INT16U UartInit(UART_CFG *psCfg);
```

parameters
psCfg UART parameters

return value
none

6.5.39 UartLinestatIntStat

Checks if the receiver line status interrupt is enabled.

defined in
msl.h

synopsis

```
INT16U UartLinestatIntStat(void);
```

parameters
none

return value
1, if receiver line status interrupt is enabled.
0, if receiver line status interrupt is disabled.

6.5.40 UartLineStatus

Returns the contents of the line status register. Please note that reading the line status register clears overrun errors only. All other errors must be cleared by reading the errornous data.

defined in
msl.h

synopsis
```
INT16U UartLineStatus(void);
```

parameters
none

return value
contents of the line status register

6.5.41 UartReceive

Reads one character from the receive buffer register of the UART. This function does not check for available data, therefore *UartRxReady* should be called before to check if characters are available.

defined in
msl.h

synopsis
```
char UartReceive(void);
```

parameters
none

return value
character from the receive buffer register. If it is empty, the last value is repeated.

6.5.42 UartRxIntStat

Checks if the receiver data-ready and the receiver timeout interrupt is enabled.

defined in
msl.h

synopsis
```
INT16U UartRxIntStat(void);
```

parameters
```
void UartRxIntStat(void);
```

return value
1, if receiver data-ready and the receiver timeout interrupt is enabled.

0, if receiver data-ready and the receiver timeout interrupt is disabled.

6.5.43 UartRxReady

Checks, if the receive holding register is empty. Application software should call this function before it calls *UartReceive* to read a character.

defined in
msl.h

synopsis
```
INT16U UartRxReady(void);
```

parameters
none

return value
TRUE: at least one character available
FALSE: receiver holding register is empty

6.5.44 UartSetRts

Signals 'request-to-send' on the RTS line. The RTS line must be controlled by application software if it was enabled by the call to UartInit.

defined in
msl.h

synopsis
```
void UartSetRts (void);
```

parameters
none

return value
none

6.5.45 UartShutdown

This function disables all UART interrupts, clears the RTS signal and installs the previous interrupt handler. After this function is called none of the UART functions, except UartInit may be called.

defined in
msl.h

synopsis
```
void UartShutdown(void);
```

parameters
none

return value
none

6.5.46 UartTransmit

This function writes the character to the transmit holding register of the UART. It does not checked whether the transmit FIFO can accept one more character. Therefore, *UartTxReady* should be called before calling this function.

defined in
msl.h

synopsis
```
void UartTransmit(char cTxChar);
```

parameters
cTxChar character to transmit

return value
none

6.5.47 UartTxDone

Checks, if the UART has transmitted all available characters. Application software can use this function to ensure that no more characters are in the transmit FIFO. When the transmitter is empty, up to FIFO size + 1 characters can be written to the transmit holding register without calling *UartTxReady*.

defined in
msl.h

synopsis
```
INT16U UartTxDone(void);
```

parameters
none

return value
TRUE: the transmit FIFO of the UART is empty
FALSE: not all characters have been transmitted yet.

6.5.48 UartTxIntStat

Checks, if the transmit holding register empty interrupt is enabled.

defined in
msl.h

synopsis
```
INT16U UartTxIntStat(void);
```

parameters
none

return value
1, if transmit holding register empty interrupt is enabled.
0, if transmit holding register empty interrupt is disabled.

6.5.49 UartTxReady

Checks, if the transmit holding register is empty. Application software should call this function before it calls *UartTransmit* to send a character.

defined in
msl.h

synopsis
```
INT16U UartTxReady(void);
```

parameters
none

return value
TRUE: UART can accept at least one more character.
FALSE: UART can accept no more character, the transmit FIFO is full.

7 FPGA Development Support

FPGA Development is supported by a separate FPGA development package. This package contains the FPGA design of the DSP master BSP as a project with most parts of the design provided as VHDL source code. The user can add own functions to the DSP master BSP or can create a totally different FPGA design. For the latter, a framework with an empty FPGA design is provided. Together with the FPGA development package, development tools from Xilinx [2] are required.

8 List of Abbreviations Used in this Document

API	application programming interface
BSP	board support package: a combination of software and FPGA design that provides a dedicated functionality to the UC1394a-3 MCM
CCS	Code Composer Studio –TI's development environment
CPU	central processing unit = processor
DSP	Digital Signal Processor
EMIF	external memory interface – an interface of the DSP
FIFO	first in first out; a special type of memory
firmware	software installed on the UC1394a-3 MCM (firmly installed software)
FPGA	field programmable gate array
I^2C	inter integrated circuit – a low speed interface between integrated circuits
KB	kilobyte = 1024 byte
KBps	KB per second
LED	light emitting diode
LLC	IEEE1394 link layer controller
LSB	least significant bit or byte
MB	Megabyte = 1204 KB = 1048576 byte
MBps	Megabytes per second
Mbps	Megabits per second
McBSP	multi-channel buffered serial port – a peripheral of the DSP
MCM	multi chip module
ML	micro-line®, a proprietary quasi-standard for micro-controller buses defined by Orsys
MSB	most significant bit or byte
n/a	not available
Phy	IEEE1394 physical layer transceiver
RAM	random access memory
SDRAM	synchronous dynamic random access memory
ROM	read only memory
SDK	software development kit
TBC	to be changed = value not 100% tested and may change in future
TBD	to be defined = value is not yet specified
TI	Texas Instruments
UART	universal asynchronous receiver transmitter

9 Literature references

Further information that is not covered in this user's guide can be found in the documents listed below. References to this list are given in square brackets throughout this document. The documents are listed by title, author and literature number or file name

[1] *Texas Instruments website at www.ti.com*
[2] *Xilinx website at www.xilinx.com*
[3] *TMS320VC5501 Fixed-Point Digital Signal Processor Data Manual,* TI, SPRS206
[4] *TMS320VC5502 Fixed-Point Digital Signal Processor Data Manual,* TI, SPRS166
[5] *TMS320VC5501/5502 DSP Host port Interface (HPI),* TI, SPRU620
[6] *TMS320VC5501/5502 DSP Universal Asynchronous Receiver/Transmitter Reference Guide,* TI, SPRU597
[7] *TMS320VC5501/5502 Timers Reference Guide,* TI, SPRU618
[8] *TMS320C55x DSP CPU Reference Guide,* TI, SPU371
[9] *TMS320C55x DSP Peripherals Reference Guide,* TI, SPRU317
[10] *TMS320C55x Assembly Language Tools User's Guide,* TI, SPRU280
[11] *TMS320C55x Optimizing C/C++ Compiler User's Guide,* TI, SPRU281
[12] *FireWire System architecture* by Don Anderson, Mind Share Inc., ISBN 0-201-48535-x
[13] *Spartan-3 FPGA Family: DC and Switching Characteristics,* Xilinx, ds099
[14] *UC1394a-3 Hardware Reference Guide*, Orsys, DSP_hrg.pdf
[15] *DSP Master BSP User's Guide for the UC1394a-3 MCM*, Orsys, DSP_master_BSP_UG
[16] *User's Guide micro-line® Power Supply Kit*, Orsys, Power_Supply.pdf
[17] *User's Guide DCAM API*, Orsys, DCAM_UG.pdf
[18] UC1394a Small Carrier User's Guide, Orsys, UC_SC_HRG.pdf